

1 TITLE OF THE INVENTION2 **Method and Network for Interconnecting Separate Multicast Channels**3 **Acquired for Separate Bus Systems**4 BACKGROUND OF THE INVENTION5 Field of the Invention

6 The present invention relates generally to serial bus networks, and
7 more specifically to a standardized serial bus network such as IEEE Std 1394-
8 1995 or IEEE Std 1394a-2000 (hereinafter IEEE 1394 standard) in which bus
9 bridges are used to interconnect serial buses and TCP/IP protocol is used for
10 inter-bridge communications.

11 Description of the Related Art

12 Recent attentions have increasingly been focused on the high speed
13 transport capability of the IEEE 1394 serial bus network to promote
14 multimedia communications. One such effort has culminated in the IP over
15 IEEE 1394 protocol (RFC 2734) developed by the IETF (Internet Engineering
16 Task Force) to support the Internet Protocol. The IP over IEEE 1394 protocol
17 defines a method in which IP packets are transmitted in unicast, multicast
18 and broadcast modes. According to the IP over IEEE 1394 protocol,
19 “asynchronous packets” are used for transmitting unicast messages and
20 “asynchronous stream channels” are used for transmitting multicast and
21 broadcast messages. Multicast channel allocation protocol is also defined for
22 allocating an asynchronous stream channel to a number of nodes attached to
23 a common bus.

24 The Serial Bus architecture supports multiple bus networks via bus
25 bridges. A bus bridge normally eavesdrops on the bus, ignoring all

1 transactions between local addresses but listening for remote transactions.
2 When the bus bridge receives a packet for a remote address, it forwards the
3 packet to an adjacent bus. After initialization, the bus bridges are transparent
4 to the system. Bus bridges are also used to segment a large system into a
5 number of small bus systems.

6 However, the multicast channel allocation protocol limits the reachable
7 extent of multicast transmissions to only one bus system. While unicast and
8 broadcast messages can be transmitted between multiple bus system via bus
9 bridges, the bus bridges allow no inter-bridge multicast transmissions.

10 Therefore, there exists a need to provide bus bridges capable of
11 retransmitting multicast packets from a multicast group of one bus system to
12 a multicast group of another bus system. If a multiple bus network has three
13 or more bus systems, intermediate bus systems must be capable of acquiring
14 an asynchronous stream channel for retransmitting multicast messages from
15 source to destination bus systems. In addition, such intermediate bus
16 systems must also be capable of acquiring an asynchronous stream channel
17 for multicast transmission even if their nodes are all receive-only nodes
18 which are currently not designed to acquire an asynchronous stream channel.

19 SUMMARY OF THE INVENTION

20 It is therefore an object of the present invention to provide a packet
21 communication method and network for transmitting multicast packets
22 across bus systems.

23 According to a first aspect of the present invention, there is provided a
24 packet communication method for a network having a plurality of bus
25 systems interconnected by at least one bus bridge, each of the bus systems

1 including at least one node, wherein the bus systems, the bridge and the node
2 are in compliance to a serial bus standard. The method is characterized in
3 that the bus bridge establishes a connection between a first channel used in a
4 first bus system for transmission of packets to a first multicast address and a
5 second channel used in a second bus system for transmission of packets to a
6 second multicast address if the first and second multicast addresses are equal
7 to each other.

8 According to a second aspect, the present invention provides a packet
9 communication method for a network having a plurality of bus systems
10 interconnected by at least one bus bridge, each of the bus systems including
11 at least one node, wherein the bus systems, the bridge and the node are in
12 compliance to a serial bus standard. The method is characterized in that at
13 least one node on each of the bus systems, when initiating a multicast packet
14 transmission to a multicast group of the bus system, acquires a channel to be
15 used for the multicast packet transmission and broadcasts a message
16 pertaining to the channel, and the bus bridge establishes a connection
17 between channels acquired for different bus systems when the message is
18 received from each of the different bus systems.

19 According to a third aspect, the present invention provides a packet
20 communication method for a network having an intermediate bus system
21 connected between first and second bus systems by first and second bus
22 bridges, each of the bus systems including at least one node, wherein the bus
23 systems, the bridge and the node are in compliance to a serial bus standard.
24 The method is characterized in that at least one node on each of the bus
25 systems acquires a channel to be used for multicast packet transmission and

1 broadcasts a message pertaining to the channel and a multicast group when
2 initiating a multicast packet transmission to the multicast group. The first
3 bus bridge acquires an interconnection channel if there is no node in the
4 intermediate bus system participating in the multicast group and if two of the
5 message having an identical multicast address are received, one from the first
6 bus system and the other from the second bus system, broadcasts a message
7 pertaining to the interconnection channel and the multicast group and
8 connects a first end of the interconnection channel to the channel acquired for
9 the first bus system. The second bus bridge connects a second end of the
10 interconnection channel to the channel acquired for the second bus system
11 when the message is received from the first bus bridge.

12 According to a fourth aspect of the present invention, there is
13 provided a bus bridge for interconnecting a plurality of bus systems of a
14 packet communication network. Each of the bus systems includes at least
15 one node, wherein the bus systems, the bridge and the node are in
16 compliance to a serial bus standard. The bus bridge establishes a connection
17 between a first channel used in a first bus system of the plurality of bus
18 systems for transmission of packets to a first multicast address and a second
19 channel used in a second bus system of the bus systems for transmission of
20 packets to a second multicast address if the first and second multicast
21 addresses are equal to each other and the first and second channels have
22 different channel identifiers from each other.

23 BRIEF DESCRIPTION OF THE DRAWINGS

24 The present invention will be described in detail further with reference
25 to the following drawings, in which:

1 Fig. 1 is a block diagram of a multi-bus communication network of the
2 present invention;

3 Fig. 2 shows details of a packet used in the communication network;

4 Fig. 3 is a block diagram of each bus bridge of the network;

5 Fig. 4 is a sequence diagram of the operation of a first embodiment of
6 the present invention when inter-channel connection is established;

7 Fig. 5A shows a channel acquisition enquiry packet sent from a first
8 multicast transmit node;

9 Fig. 5B shows a mapping data packet sent from the first multicast
10 transmit node;

11 Fig. 5C shows a mapping table of first and second bus bridges when
12 the mapping data packet of Fig. 5B is received;

13 Fig. 6A shows a channel acquisition enquiry packet sent from a second
14 multicast transmit node;

15 Fig. 6B shows a mapping data packet sent from the second multicast
16 transmit node;

17 Fig. 6C shows a mapping table of the first bus bridge when the
18 mapping data packet of Fig. 6B is received;

19 Fig. 6D shows a mapping table of the second bus bridge when the
20 mapping data packet of Fig. 6B is received;

21 Fig. 7 is a flowchart of the operation of each bus bridge when inter-
22 channel connection is established;

23 Fig. 8 is a sequence diagram of the operation of the first embodiment
24 of the present invention when the inter-channel connection is cleared;

25 Fig. 9 is a flowchart of the operation of each bus bridge when the inter-

1 channel connection is cleared;

2 Fig. 10 is a sequence diagram of the operation of a second embodiment
3 of the present invention in which inter-channel connection is established
4 between terminal bus systems via an intermediate bus system;

5 Fig. 11A shows a mapping table created by first and second bridges
6 when they received channel acquisition enquiry packets respectively from
7 transmit nodes on the terminal bus systems;

8 Figs. 11B and 11C show channel acquisition enquiry packets
9 transmitted from the first and second bus bridges respectively after they have
10 created their mapping table of Fig. 11A;

11 Fig. 11D shows a mapping data packet sent from one of the bus
12 bridges when a channel is acquired;

13 Fig. 12 is a flowchart of the operation of each of the bridges according
14 to the second embodiment of the present invention when inter-channel
15 connection is established;

16 Fig. 13 is a sequence diagram of the operation of the second
17 embodiment for illustrating the process of clearing the inter-channel
18 connection;

19 Fig. 14 is a sequence diagram of the operation of a third embodiment
20 of the present invention in which an inter-channel connection is established
21 between a transmit node and a receive-only node;

22 Fig. 15A shows a mapping table of first and second bus bridges when
23 the transmit node of Fig. 14 broadcasts a mapping data packet after acquiring
24 a channel;

25 Figs. 15B and 15C show respective mapping tables of the first and

1 second bridges when the receive-only node broadcasts a mapping data
2 packet after acquiring a channel; and

3 Fig. 16 is a sequence diagram of the operation of the third embodiment
4 for illustrating the process of clearing the inter-channel connection.

5 DETAILED DESCRIPTION

6 Referring now to Fig. 1, a multiple bus network of the present
7 invention is shown comprising bus systems 109, 110 and 111 interconnected
8 by bus bridges 107 and 108. Each bus bridge has two ports respectively
9 designated A and B. Each of these ports has an IEEE-1394 compliant data
10 link layer for interfacing the IEEE-1394 serial bus of its neighboring bus
11 system. Nodes 101 and 102 are serially interconnected by the bus 109 which
12 is connected at one end to the port A of bridge 107. Nodes 103 and 104 are
13 serially interconnected by the bus 110 which are connected at one end to the
14 port B of bridge 107 and at the other end to the port A of bridge 108. Finally,
15 nodes 105 and 106 are serially connected by the bus 111 that is connected at
16 one end to the port B of bridge 108. All bus systems are IEEE-1394 serial bus
17 systems and all nodes are also IEEE-1394 compliant devices. For each bus
18 system, there is one node that operates as an Isochronous Resource Manager
19 (IRM). In the illustrated network, nodes 102, 104 and 106 are the IRM node.
20 Each node of the network is composed of a line interface for interfacing the
21 node to the associated bus, a packet assembler/disassembler, timer circuitry,
22 a memory and a control unit that provides overall control of the node
23 components.

24 As shown in Fig. 3, each bus bridge includes a packet switching unit
25 210 connected between its ports A and B, a packet assembler/analyizer 211 for

1 assembling a transmit packet and analyzing a received packet, timer circuitry
2 212 for providing a timing action, and a memory 213 for creating a mapping
3 table according to received packets announcing information pertaining to
4 channel and multicast address and so on. A control unit 214 for overall
5 control of the bridge components. When the control unit 214 of each bus
6 bridge receives two messages, one from the port A and the other from the
7 port B, it causes the packet assembler/ analyzer 211 to determine whether
8 they contain the same multicast address and different channel identifiers
9 from each other. If so, the control unit sets the packet switching unit 210 so
10 that it establishes a connection between two channels acquired respectively
11 for the bus systems to which the ports A and B are directly connected.
12 Specifically, when a multicast packet is received at the port A, the packet
13 switching unit 210 translates the channel identifier contained in the header of
14 the multicast packet to a channel identifier used in the bus system that is
15 connected to the port B and forwards the header-translated multicast packet
16 to the port B.

17 Each node of the multiple bus network operates in compliance with
18 TCP/IP and IP over IEEE 1394 protocol (RFC 2734) to transfer IP packets
19 within its own bus system. Each bus bridge has the ability to retransmit
20 unicast packets and broadcast packets between neighboring bus systems.

21 Each node of the network is assigned an IP address "A1" which is
22 used as a member address of a multicast group in which the node desires to
23 participate. User datagram protocol (UDP) will be used to transmit multicast
24 packets. A multicast group is therefore identified by the IP address A1 and
25 the user datagram protocol.

1 Control messages used by the nodes and bus bridges include a number
2 of control data fields as shown in Fig. 2. These include a node number field
3 201, a message type field 202, a channel number field 203, and a destination
4 address field 204. The node number field 201 contains a node identifier
5 which consists of a bus identifier of the attached bus system and a node
6 identifier of the node in that bus system. Thus, node 101, for example, is
7 assigned a node number which is a sum of the identifiers of bus system 109
8 and node 101. The message type field 202 contains four message types
9 including "channel acquisition enquiry", "report from transmit node",
10 "report from receive node" and "channel transfer enquiry". The channel
11 acquisition enquiry message is used by a node when it determines whether a
12 channel for multicast transmission has been acquired. The "report from
13 transmit node" message is used by both transmit-only nodes and
14 transmit/receive nodes. This message contains mapping data indicating the
15 relationship between a multicast group address and an assigned channel
16 number. The "report from receive node" message is used by receive-only
17 nodes and the bus bridges. This message contains mapping data indicating a
18 relationship between a multicast group address and a channel number. The
19 channel number contained in both types of report message is stored in a
20 channel management database. The channel transfer enquiry message is
21 used by a node which has gained ownership of a channel for multicast
22 transmission when it makes a search through the network for a node to hand
23 over the channel ownership at the end of the transmission.

24 A channel number set in the channel number field 203 ranges from "0"
25 to "63" except for the number "31". The destination address field 204

1 contains an IP address selected from the range between "224. 0. 0.1" to "239.
2 255. 255. 255".

3 The following is a description of the transaction sequence of the
4 multiple bus system between bus systems 109 and 110 with the aid of a
5 sequence diagram shown in Fig. 4 when nodes 101 and 103 are requesting a
6 channel for multicast transmission to a multicast group. For purposes of
7 explanation, the node 101 is the first to send a channel acquisition enquiry
8 packet.

9 As shown in Fig. 5A, the node 101 formulates a channel acquisition
10 enquiry packet by setting its node identifier plus the identifier of the bus 109
11 in the node number field 201 of the packet, setting a "channel acquisition
12 enquiry" message in the message type field 202, and an IP address "A1" as a
13 multicast group address in the destination address field 204. Specifically, the
14 multicast group address A1 is specified by a TCP/IP compliant application
15 program installed on the node 101. Then, the node 101 broadcasts this
16 channel acquisition enquiry packet to the network and waits for a reply from
17 the network to determine whether a channel has been acquired for the
18 multicast group (procedure 301). As illustrated, the packet propagates
19 through the network, passing through all intermediate nodes and bus
20 bridges, and reaches the node 106 at the far end of the network.

21 If no reply is returned from the network, the node 101 sends a channel
22 request packet to the IRM node 102 to acquire a channel "C1" for multicast
23 transmission (procedure 302).

24 As shown in Fig. 5B, the node 101 formulates a mapping data packet
25 by setting its node number field 201 with the same information as the channel

1 acquisition enquiry packet, the message type field 202 with the "report from
2 transmit node" message, the channel number field 203 with C1, and the
3 destination address field 204 with A1. Node 101 broadcasts this mapping
4 data packet to the network at periodic intervals (procedure 303).

5 Bus bridges 107 and 108 each receive the mapping data packet through
6 their port A and map the contents of the mapping data packet to the port A in
7 their mapping tables shown in Fig. 5C (procedure 304).

8 Node 101 then starts multicasting asynchronous stream packets over
9 the assigned channel C1 (procedure 305). Although these multicast packets
10 are received and retransmission by the node 102 to the bus bridge 107, they
11 are not repeated by the bus bridge 107, as illustrated in Fig. 4.

12 When the node 103 wishes to send packets to a multicast group during
13 the time the node 101 continues its multicast transmissions, the node 103
14 broadcasts a channel acquisition enquiry packet to determine if a channel has
15 been acquired for the multicast group (procedure 306). If the multicast group
16 of node 103 has the same multicast address A1, the channel acquisition
17 enquiry packet contains the same information as those of the channel
18 acquisition enquiry packet used by the node 101 except that its node number
19 field 201 contains the identifiers of bus 110 and node 103, as shown in Fig. 5A.
20 Although the node 101 has acquired a channel for the multicast group of
21 address A1, it does not respond to the channel acquisition enquiry packet
22 from the node 103. Therefore, if no reply is returned from within the same
23 bus system, the node 103 sends a channel request packet to the IRM node 104
24 to acquire an asynchronous channel C2 for multicast transmission (procedure
25 307).

1 As shown in Fig. 5B, the node 103 formulates a mapping data packet
2 by setting its node number field 201 with the same information as the channel
3 acquisition enquiry packet, the message type field 202 with the "report from
4 transmit node" message, the channel number field 203 with C2, and the
5 destination address field 204 with A1. Node 103 broadcasts this mapping
6 data packet to the network at periodic intervals (procedure 308).

7 Bus bridge 107 receives the mapping data packet from the node 103
8 through its port B and updates its own mapping table (Fig. 5C) by storing the
9 contents of the received packet in the port B, whereas the bus bridge 108
10 receives this packet through its port A and updates its own mapping table of
11 Fig. 5D by storing the contents of the received packet in the port A
12 (procedure 309).

13 Referring to the flowchart of Fig. 8, each of the bus bridges 107 and 108
14 is monitoring the bus systems to determine if they have received two
15 mapping data packets, one through their port A and the other through their
16 port B (step 401). This is achieved by the bus bridge 107 by making a
17 comparison between the mapping table of Fig. 5C and that of Fig. 6C and is
18 achieved in the bus bridge 108 by making a comparison between the
19 mapping table of Fig. 5C and that of Fig. 6D. Since the decision at step 401 is
20 affirmative only in the bus bridge 107, the bridge 108 returns to the starting
21 point of the routine, while the bridge 107 proceeds to step 402 to determine
22 whether the mapping data packets have the same multicast address. If this is
23 the case, the bus bridge 107 makes a further test on their node number fields
24 to determine whether they indicate that the packets have been received from
25 the bus systems to which the ports of bridge 107 are directly connected (step

1 403). If so, the bridge 107 proceeds to step 404 to examine the message type
2 fields in the port-A and port-B entries of mapping table (Fig. 5C) to determine
3 if they contain a "report from receive node" message. Since the message type
4 fields of both entries contain a "report from transmit node" message, the
5 decision at step 404 is negative and the bridge 107 advances to step 405 to
6 establish a connection between the channels respectively acquired by the
7 nodes 101 and 103 through the ports A and B.

8 Since the "report from receive node" message indicates that there is no
9 sender at all, no packets exist for multicast transmission. Therefore, if such a
10 message is contained in at least one of these mapping tables, the bus bridge
11 returns from step 404 to the starting point of the routine.

12 Returning to Fig. 4, the establishment of the connection between the
13 ports A and B of bus bridge 107 is indicated by procedure 310. More
14 specifically, the bus bridge 107 establishes the connection by converting the
15 channel number C1 of asynchronous stream packets received through its port
16 A to the channel number C2 of the mapping table of Fig. 5C when forwarding
17 the received packets to its port B and converting the channel number C2 of
18 asynchronous stream packets received through its port B to the channel
19 number C1 of the mapping table of Fig. 5C when forwarding the received
20 packets to its port A.

21 Following the transmission of the mapping data packet (procedure
22 408), the node 103 proceeds to start transmitting asynchronous stream
23 packets (procedure 311). These multicast packets are retransmitted by bridge
24 107 to the nodes on the bus system 109 by performing the channel number
25 conversion process described above. Likewise, the multicast packets which

1 are subsequently transmitted from the node 101 are repeated through the
2 bridge 107 to the bus system 110 (procedure 312).

3 In Fig. 8, when the node 101 ceases its multicast transmission
4 (procedure 501), it formulates a channel transfer enquiry packet by setting its
5 message type field with a channel transfer message and setting the other
6 fields with the same information as those of the mapping data packet of Fig.
7 5B. Node 101 broadcasts this transfer enquiry packet through the network
8 (procedure 502) and starts a timer for setting a later time instant for
9 transmission of a channel transfer request to the IRM node 102.

10 Upon receipt of the transfer enquiry packet at procedure 502, the bus
11 bridge 107 performs a routine as shown in Fig. 9.

12 In Fig. 9, the bridge 107 determines whether the bus identifier
13 contained in the node number field of the packet indicates that the packet has
14 been received from the bus system to which the bridge 107 is directly
15 connected (step 602). If so, the bridge 107 stores the information contained in
16 the node number field 201, the channel number C1 and the multicast address
17 A1 of the packet in memory (step 603) and starts a timer (step 604). At step
18 605, the bus bridge 107 analyzes the contents of the received packet and
19 determines if the bus identifier and multicast address of the packet match the
20 stored bus identifier and multicast address and if the packet's message type
21 field contains a "report from transmit node" or a "report from receive node".
22 If the decision is affirmative, flow returns to the starting point of the routine.
23 Otherwise, the bridge 107 proceeds to step 605 to determine whether the
24 timer has run out of a predetermined timeout period "Ta" (step 605). If the
25 timer is still running (step 606), step 605 is repeatedly executed. If step 605

1 yields affirmative decision in the repeated execution, the bus bridge 107
2 clears the inter-channel connection, and returns to the starting point of the
3 routine (step 607).

4 In the sequence diagram of Fig. 8, the clear-down of the connection
5 between the bus systems 109 and 110 occurs when the timeout period "Ta"
6 has elapsed (procedure 503).

7 On the other hand, the node 101 started its own timer (procedure 502).

8 This timer is set to expire when timeout period "Td" greater than "Ta" has
9 elapsed. Therefore, this timer expires after the bus bridge 107 cleared the
10 inter-bus connection. In response to the running out of its own timer, the
11 node 101 sends a channel transfer request packet to the IRM node 102 to
12 restore the ownership of the acquired channel (procedure 504). The reason
13 for the earlier occurrence of the channel clear-down by bridge 107 than the
14 restoration of channel ownership by node 101 is to ensure against possible
15 delivery of packets from the bus system 110 to wrong destinations on the bus
16 109.

17 In a second embodiment of the present invention, the bus bridges 107
18 and 108 operate to establish inter-channel connections between the terminal
19 bus systems 109 and 111 via the intermediate bus system 110.

20 The description of the operation of the second embodiment proceeds
21 with the aid of a sequence diagram of Fig. 10 by assuming that the nodes 101
22 and 105 are the transmit nodes of multicast transmission to the same address
23 A1 and that the node 101 is the first to initiate channel acquisition.

24 Since the node 101 is the first to initiate channel acquisition,
25 procedures 301 through 305 of Fig. 4 are repeated in the sequence diagram of

1 Fig. 10.

2 Thus, the bus bridges 107 and 108 store the contents of mapping data
3 packet broadcast from node 101 in the port-A entry of a mapping table as
4 shown in Fig. 11A (procedure 304) and the node 101 acquires the channel C1
5 from the IRM node 102 for multicast transmission (procedure 305).

6 Node 105 then broadcasts a channel acquisition enquiry packet for
7 multicast transmission (procedure 701), acquires a channel C3 from the IRM
8 node 106 (procedure 702), and broadcasts a mapping data packet (procedure
9 703). As a result, the bus bridges 107 and 108 store the contents of mapping
10 data packet broadcast from the node 105 in the port-B entry of the mapping
11 table of Fig. 11A (procedure 704).

12 Bus bridges 107 and 108 then attempt to establish a connection
13 between the bus systems 109 and 111 by initially sending channel acquisition
14 enquiry packets in sequence (procedure 705, 706), mutually examining the
15 contents of their packets to determine the bridge to acquire a channel from
16 the IRM node (procedure 707), and broadcasting a mapping data packet from
17 that bridge (procedure 708) and finally establishing inter-channel connections
18 (procedure 709).

19 In Fig. 12 where details of procedures 705 through 709 are illustrated,
20 each of the bus bridges monitors the mapping table of Fig. 11A for detecting
21 when two mapping data packets are received from nodes on different bus
22 systems, one through the port A and the other through the port B (step 801)
23 and yields an affirmative decision. At step 802, each bus bridge determines
24 whether the both entries contain the same multicast destination A1. If so,
25 flow proceeds to step 803 to check to see if the node number fields of the

1 mapping table indicate that one of the nodes is on a bus system to which the
2 bridge is directly connected and the other node is on a bus system to which
3 the bridge is not directly connected.

4 If this is the case, each bus bridge proceeds to step 804 to broadcast a
5 channel acquisition enquiry packet and receives a channel acquisition
6 enquiry packet sent from another bridge (step 805). The details of the channel
7 acquisition enquiry packets sent from bridges 107 and 108 are shown in Figs.
8 10B and 10C, respectively.

9 At step 806, each bus bridge compares the contents of its own
10 broadcast channel acquisition enquiry packet with those of the received
11 C.A.E. packet and determines whether they have the same bus identifier and
12 multicast address. If the decision at step 806 is affirmative, flow proceeds to
13 step 807 to check to see if the local node (bridge) identifier is greater than the
14 node identifier of the remote bridge. If so, the local bridge acquires a channel
15 (C2) from the IRM node (step 808) and broadcasts a mapping data packet
16 (step 809).

17 Therefore, if the node identifier of bridge 107 is greater than that of
18 bridge 108, the bridge 107 is given higher priority to acquire a channel from
19 the IRM node 104, as indicated by procedure 707 in Fig. 10, and broadcasts a
20 mapping data packet. Details of this packet are shown in Fig. 11D.

21 The bridge to which higher priority is assigned establishes an inter-
22 channel connection (step 810) by converting the channel identifier given in
23 the mapping table of Fig. 11A to the channel identifier contained in the
24 mapping data packet of Fig. 11D.

25 Conversely, if the node identifier of the local bridge is not greater than

1 that of the remote bridge, the local bridge is given lower priority and
2 proceeds from step 807 to step 811 to check to see if a mapping data packet is
3 received from the remote bridge within a specified time interval. If the
4 decision at step 811 is affirmative, flow proceeds to step 810 to establish an
5 inter-channel connection. If no mapping data packet is received, the decision
6 at step 811 is negative and the bridge of the lower priority proceeds to step
7 808 to acquire a channel C2 from the IRM node 104 and broadcasts a
8 mapping data packet (step 809). The priority can be alternatively determined
9 by having the bridges 107 and 108 select a random number. The bridge that
10 selected a greater value of random number is given the higher priority.

11 With the inter-channel connections being established at bridges 107
12 and 108, the nodes 101 and 105 transmit their multicast packets to the
13 network (procedures 710, 711).

14 A procedure for restoring the ownership of channels C1 and C2
15 respectively acquired by the node 101 and the bridge 107 is illustrated in Fig.
16 13.

17 In Fig. 13, when the node 101 ceases its multicast transmission
18 (procedure 901), it broadcast a channel transfer enquiry packet through the
19 network (procedure 902) and starts a timer that is set expire at the end of a
20 period T_d for later transmission of a channel transfer request to the IRM node
21 102. In response to this transfer enquiry packet, the bus bridge 107 performs
22 the routine of Fig. 9 to clear down the inter-channel connection between the
23 bus systems 109 and 110 when the timer expires at the end of the period T_a
24 (procedure 903). Bus bridge 107 broadcasts a channel transfer enquiry packet
25 (procedure 904). Bridge 108 stores this packet (procedure 905) and performs

1 the routine of Fig. 9 to clear down the inter-channel connection at the end of a
2 timeout period T_c (procedure 906). At the end of a timeout period T_d from
3 the instant the transfer enquiry packet is broadcast, the node 101 informs the
4 IRM node 102 of the restoration of the channel C_1 (procedure 907). Likewise,
5 the bridge 107 communicates the restoration of the channel C_2 to the IRM
6 node 104 at the end of a timeout period "Te" from the instant it performed
7 the broadcasting of the transfer enquiry packet (procedure 908).

8 Fig. 14 illustrates a further feature of the present invention in which
9 inter-bus multicast transmission is implemented between two neighboring
10 bus systems, one having at least one transmit node and the other only one
11 receive-only node. In the illustrated embodiment, the node 101 on bus 109 is
12 the transmit node and the node 103 on bus 110 is the receive-only node.

13 The operation of the network starts with the node 101 broadcasting a
14 channel acquisition enquiry packet (Fig. 5A) as in the previous embodiments.
15 Therefore, the network responds to this packet by performing procedures 301
16 through 305 in the same manner as described above. Thus, the node 101 is
17 broadcasting a mapping data packet of Fig. 5B at periodic intervals for
18 announcing the information necessary for the receive node 103 to acquire a
19 channel.

20 As indicated by procedure 1001 in the sequence diagram of Fig. 14, the
21 node 103 is activated as a receive node to participate in the multicast group of
22 bus system 109 and waits for a periodic broadcast of mapping data from the
23 node 101. When the mapping data packet is broadcast (procedure 1002), the
24 bus bridges 107 and 108 create a mapping table (see Fig. 15A) (procedure
25 1003). Simultaneously, the receive node 103 creates the same mapping table

1 in its own memory (procedure 1004). Node 103 then broadcasts a channel
2 acquisition enquiry packet of Fig. 5A for a response from the bus 110
3 (procedure 1005). Since no channel is acquired for the bus system 110, the
4 node 103 receives no response, and hence it acquires a channel C2 from the
5 IRM node 104 (procedure 1006). At periodic intervals, the receive node 103
6 broadcasts a mapping data packet which is similar to the packet of Fig. 5
7 except that its message type field contains a "report from receive node"
8 message, instead of the "report from transmit node" message (procedure
9 1007).

10 Upon receipt of the mapping data packet (procedure 1007), the bridge
11 107 stores the contents of the received packet into the port-B entry of the
12 mapping table as shown in Fig. 15B and the bridge 108 stores them into the
13 port-A entry of the mapping table as shown in Fig. 15C. Both of the bridges
14 107, 108 then perform the routine of Fig. 7. Since the bus bridge 107 received
15 mapping data packets through its ports A and B, the decision at step 801 is
16 affirmative. Bridge 107 successively performs steps 802 and 803. Decisions at
17 both of these steps are affirmative, the bridge 107 proceeds to step 804. Since
18 the port-A entry of mapping table (Fig. 15B) contains a "report from transmit
19 node" message, the decision at step 804 is negative, the channel C1 on the bus
20 system 109 and the channel C2 on the bus system 110 are interconnected by
21 the bridge 107 at step 805.

22 In the sequence diagram of Fig. 14, the establishment of the inter-
23 channel connection is indicated by numeral 1008.

24 Multicast transmission from the transmit node 101 to the bus system
25 110 (procedure 1009). Node 103 is now able to receive multicast packets from

1 the transmit node 101.

2 Fig. 16 illustrates a sequence in which the transmit node 101 and
3 receive node 103 restore the acquired channels to their IRM node. When the
4 transmit node 101 ceases its multicast transmission (procedure 1101), it
5 broadcasts a channel transfer enquiry packet and starts a timer with period
6 T_d (procedure 1102). Bridge 107 receives this transfer enquiry packet and
7 stores its contents in memory and starts its timer with timeout period T_a .
8 Node 103 also receives this packet and stores its contents in memory and
9 starts a timer with a timeout period T_b and starts monitoring the channel for
10 detecting a packet from a node wishing to take over the ownership of the
11 acquired channel C1 (procedure 1103). This packet contains the identifier of
12 bus 109, a "report from transmit node" message and address A1. Bridge 107
13 now performs the clear-down routine of Fig. 9, so that the connection
14 between the channels C1 and C2 is cleared at the end of timeout period T_a
15 (procedure 1104). Transmit node 101 restores the channel C1 to the IRM node
16 102 at the end of timeout period T_d of its own timer (procedure 1105). At the
17 end of timeout period T_b (where $T_b > T_a$), the node 103 terminates the
18 channel monitoring (procedure 1106).

19 Receive-only node 103 broadcasts a channel transfer enquiry packet
20 and activates a timer with a timeout period T_c (procedure 1107). During this
21 period, the node 103 monitors the channel for detecting a channel takeover
22 packet from a node containing the identifier of bus 110, either a "report from
23 transmit node" or "report from receive node" message and address A1. If the
24 node 103 fails to detect such a channel takeover packet within the set period
25 T_c , it returns the ownership of the channel C2 to the IRM node 104
26 (procedure 1108).